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Spruce Beetles in Blowdown

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Attack and beetle densities varied significantly among trees and among the top, lateral, and bottom surfaces of the bole, but insignificantly throughout the infested portion of any one surface. These characteristics are discussed in relation to outbreak potential and biological evaluation procedures.

Keywords: Spruce beetle, *Dendroctonus rufipennis*

Management Implications

Forest entomologists conducting biological evaluations of beetle populations in windthrown trees should (1) take a set of samples (top, lateral, and bottom surfaces) from any place along the infested portion of the bole, excluding 5 feet at each end; (2) sample as many trees as possible; and (3) determine the number and size of windthrown trees as well as the average d.b.h. of the surrounding standing trees. The beetle population and its threat to adjacent standing trees can then be estimated from this information.

Introduction

Outbreaks of the spruce beetle, *Dendroctonus rufipennis* (Kirby), have killed considerable amounts of spruce in the Rocky Mountains. Most outbreaks have originated from windthrown trees although beetle populations have also increased in the residuals in logging areas. Blowdown in Colorado in 1939 triggered a subsequent outbreak that eventually killed over 3.5 billion board feet of spruce sawtimber.

The beetle prefers downed spruce to standing trees. Downed spruce offers two obvious advantages for survival:(1) during the winter months windthrown trees are usually covered by snow which provides an insulating cover, preventing low temperatures from killing the brood and (2) snow also prevents woodpeckers, the most important predator of the beetle, from consuming the brood (Knight 1958). The reduction in mortality caused by these two factors enhances beetle survival.

Blowdowns can occur at any time; if beetle populations develop to high levels in down material, they may become a serious problem in adjacent standing trees. Although blowdowns do not always produce outbreaks, potential outbreak situations need to be identified. This study analyzed attack densities and brood production in windthrown trees in relation to subsequent beetle populations in standing trees. A secondary objective was to determine a sampling method for beetles in blowdown.

Study Areas

From 1969 to 1973, areas of windthrown spruce, *Picea engelmannii* Parry, were found on Agassiz Peak near Flagstaff, Ariz.; Mt. Graham near Safford, Ariz.; Sierra Blanca Ski Area near Ruidoso, N. Mex.; Philmont Scout Ranch near Cimarron, N. Mex.; Polvadera Mesa near Espanola, N. Mex.; Hidden Valley ski area near Estes Park, Colo.; and Iron Creek, Brush Creek district of the Medicine Bow National Forest Southeast of Saratoga, Wyo. Blowdowns on Agassiz Peak, Mt. Graham, Sierra Blanca, and Hidden Valley consisted of scattered trees along ski runs, lift lines, or in adjacent stands. The Wyoming blowdown was light unraveling of the edges of uncut stands between clearcut strips. The Philmont and Polvadera Mesa blowdowns were both in undisturbed stands, the Philmont being about 300 trees in a 25-acre, narrow strip, and the Polvadera Mesa being occasional trees scattered throughout the natural stand. The blow-

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down in these locations did not consist of entire stands but rather scattered trees or partial lengths of trees. Trees were either totally uprooted (entire root system broken and disconnected from the soil) or partially uprooted (some roots broken, some still apparently functioning).

Methods

The number of windthrown trees or parts of trees sampled in each location varied among locations (table 1). Sampling points were established along the main bole on each tree. The first point was 2 feet from the tree base or from the large end of the broken bole, depending on whether the sample tree was whole or just a broken off section. Additional points were 10 feet or multiples of 10 feet from the initial point. After the points were established, the tree was bucked into 8- to 10-foot lengths so top, lateral, and bottom 6 inch by 6 inch bark samples could be taken. When bole diameter became less than 8 inches, three samples from the same point were not possible, so lateral samples were not always taken. For those locations sampled more than once, the same trees were resampled as previously described except the second samples were taken about 1 foot up the bole from the previous sample. The number of attacks, eggs, larvae, pupae, and adults, and bole diameter at the sampling point, were recorded for each sample. Mean numbers of attacks and beetles per square foot were computed and subjected to analyses of variance testing for significant variation among trees, sampling points, and bark surfaces (i.e., top, lateral, bottom) at $P = 0.05$.

Results and Discussion

Density of Attacks

Attack densities varied significantly among trees in four of seven locations, insignificantly among sampling points (i.e., throughout the infested length) in all locations, and significantly among surfaces in five of seven locations. These sources of attack density variation are the same sources observed by McComb (1953), Massey and Wygant (1954), Nagel et al. (1957), Dyer and Taylor (1971), and Schmid (1977).

Significant variation among trees reflects resident population abundance and beetle preference. A low resident population means an overall low density of attacks as exhibited by the means for Mt. Graham, Sierra Blanca, Philmont, and Hidden Valley (table 2). However, even at low densities, the beetle selects the more shaded parts on individual windthrown trees as well as the more shaded trees, so attack densities vary significantly among trees.

Insignificant variation among sampling points within the same surface agrees with McComb's (1953) results but differs from Schmid's (1977). Although Schmid (1977) found significant variation in attack densities within the same surface on cull logs, the densities did not vary significantly if the bark surface had not been partially shaded or damaged. If the top surface has dense shade in one section and no shade on the remainder, attacks will be significantly higher in the shaded part. Similarly, if parts of the bottom surface had the bark scraped off or imbedded in the soil when the tree toppled, those places will have fewer attacks, and densities

Table 1.—Locations, sampling dates, and number of samples taken from each of the top, lateral, and bottom surfaces on windthrown trees

Location	Sampling dates	Number of trees	Number of samples per surface	Acreage of infested trees	Number of windthrown trees
Agassiz Peak, Arizona	September 5-8, 1969	13	58	40	800
	June 19-21, 1970	15	58		
	September 11-13, 1970	15	58		
Mt. Graham, Arizona	June 18-21, 1969	12	94	2	20
	September 10-12, 1969	12	94		
Sierra Blanca, New Mexico	October 14, 1969	19	19	[1]	75
	July 20, 1970	19	19		
Philmont Ranch, New Mexico	July 9-13, 1969	12	76	25	[2]300
	August 12-14, 1969	12	76		
Polvadera Mesa, New Mexico	May 25-28, 1970	15	89	8500	Unknown
Hidden Valley, Colorado	September 5, 6, 1973	15	70	[1]	< 100
Iron Creek, Wyoming	July 7-10, 1970	12	79	[1]	< 100
	August 30, 31, 1970	12	79		

[1]*Acreage value not pertinent because trees were toppled along edges of cutting areas or ski runs.*
[2]*Less than 100 spruce out of the 300 windthrown trees.*

will vary significantly along the bottom surface. Bole extremities tend to have lower attack densities, particularly on trees separated from their base, and this creates some significant variation. If these different surface conditions are not present and the surface is uniform throughout, then McComb's 1953 conclusion that attacks vary little along the bole is generally true.

The most significant variation in attack densities is among the three bole surfaces. Attack densities were usually lowest on the top and highest on the bottom (table 2). Lateral surface densities were either intermediate to top and bottom densities or were similar to bottom densities. This pattern agrees with the results of McComb (1953) and Nagel et al. (1957) for windthrown trees and with Dyer and Taylor (1971) and Schmid (1977) for logging residuals. The pattern reflects the beetles, preference for shaded locations—infesting shaded surfaces in higher densities.

Density of Beetles

Beetle densities varied significantly among trees in six of seven locations, insignificantly among sampling points (i.e., length of the infested portion), and significantly among surfaces in six of seven locations. Beetle densities reflect, as expected, the same significant sources of variation as attack densities. In general, beetles are more abundant where attack densities are greatest.

The mean number of beetles per square foot was usually lowest on the top surface, intermediate on the lateral surface, and highest on the bottom surface (table 3). This pattern reflects not only the beetles' preference for the different surfaces but also brood survival in these surfaces. Overwintering mortality (as determined from the Agassiz Peak and Sierra Blanca data in table 3) was greatest in the top surface. Mortality during summer months averaged 66, 42, and 30% for the top, lateral, and bottom surfaces, respectively, from Agassiz Peak, Mt. Graham, Philmont, and Iron Creek. Thus, beetle densities initially reflect attack densities and later, as broods mature, the mortality associated with the different surfaces. Exceptions to this pattern are caused by the shade and bark damage factors discussed in the section on attack densities.

Blowdown-Outbreak Relationships

The beetle populations in the Agassiz Peak, Sierra Blanca, Polvadera, and Iron Creek infestations did not evolve to severe outbreak status because sanitation logging or chemical control was conducted therein. Although Lessard (1976) states the suppression efforts against the Agassiz Peak and Polvadera infestations were successful, both areas experienced additional spruce beetle infestations within 5 years, which may indicate these efforts were not thorough enough. However, both infestations did have extenuating circumstances, such as additional blowdown in undisturbed stands or along the edge of cutting areas or the accumulation of logging residuals in the cut areas. These factors help maintain a high resident population which can increase dramatically in new blowdown or spread to standing trees.

Table 2.—Mean number of attacks per square foot of bark on the top, lateral, and bottom surfaces of windthrown trees[1]

Location	Dates	Surface					
		Top		Lateral		Bottom	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Agassiz Peak, Arizona	September 5-8, 1969	1.7 a	3.1	4.6 b	4.6	4.8 b	4.7
	June 19-21, 1970	3.9 a	4.9	6.6 b	5.0	7.9 b	5.1
	September 11-13, 1970	2.9 a	3.8	5.9 b	4.3	5.9 b	4.3
Mt. Graham, Arizona	June 18-21, 1969	0.3 a	1.3	1.4 ab	2.5	1.7 b	2.7
	September 10-12, 1969	0.1 a	0.9	0.7 a	1.5	0.8 a	1.8
Sierra Blanca, New Mexico	October 14, 1969	0.2 a	0.9	1.7 ab	2.0	2.9 b	2.9
	July 20, 1970	0.8 a	1.7	1.1 a	1.8	1.1 a	2.2
Philmont Ranch, New Mexico	July 9-13, 1969	0.3 a	1.2	0.7 ab	2.1	1.5 b	2.6
	August 12-14, 1969	0.5 a	1.6	0.3 a	1.1	1.0 b	1.9
Polvadera Mesa, New Mexico	May 25-28, 1970	1.0 a	3.4	2.0 a	4.1	2.5 a	5.1
Hidden Valley, Colorado	September 5, 6, 1973	0.4 a	1.5	1.0 a	2.8	1.2 a	2.2
Iron Creek, Wyoming	July 7-10, 1970	0.9 a	2.5	6.0 b	4.8	6.1 b	5.0
	August 30, 31,1970	1.0 a	2.7	6.2 b	5.6	5.8 b	4.2

[1]*Means within specific sampling dates that are followed by the same letter are not significantly different (P = 0.05).*

The Mt. Graham, Philmont, and Hidden Valley infestations either disappeared naturally or remained at low levels. These three uncontrolled infestations may have characteristics helpful in determining potential outbreaks. All had attack densities of 1 or less per square foot on the top surface, and 3 or less on the bottom surface (table 2). All had about 40 or fewer beetles per square foot on the bottom surface. The number of windthrown trees was 100 or less (300 for Philmont represents all species; less than 100 spruce), and the area of the blowdown was limited. These characteristics indicate low endemic populations which should be monitored but not suppressed. When this information is used in conjunction with the stand rating system of Schmid and Frye (1976), the potential threat to surrounding stands can be estimated.

Similarly, attack densities of 1 or more per square foot on the top, and 5 or more per square foot on the bottom; adult beetle densities of 45 or more per square foot in August-September samples from the bottom surfaces; and 100 or more infested trees seem to indicate population numbers capable of producing significant numbers of infested standing trees. This beetle potential should also be evaluated in conjunction with the stand rating system to determine the threat to standing trees.

Biological Evaluation Procedures

The data reported here forms the basis for biologically evaluating beetle populations in windthrown trees. The evaluation should (1) take one set of 6 inch by 6 inch samples (top, lateral, and bottom surfaces) from any place along the infested portion of the bole, excluding 5 feet at each end; (2) sample as many trees as possible (more than 100 samples were required to obtain a standard error of the mean within 20% of the mean for beetles per square foot in any surface in this data); and (3) determine the number, diameter at the midpoint of the infested length, and infested length of windthrown trees as well as the average d.b.h. of the surrounding standing trees.

This information can then be used to determine the number of potentially infested trees through the following calculations:

1. Infested bark area per tree

$$A = \pi d l$$

where A = average infested bark area per tree
d = mean diameter in feet at the midpoint of the infested length
l = mean infested length

2. Mean number of beetles per square foot

$$\overline{X} = n_t + 2n_l + n_b$$

where $\overline{X}$ = mean number of beetles per square foot
n_t = mean number of beetles in the top samples
n_l = mean number of beetles in the lateral samples
n_b = mean number of beetles in the bottom samples

3. Potential number of beetles available to attack

$$P = A\,\overline{X}\,N$$

where P = potential number of beetles available to attack standing trees
N = number of windthrown trees

Table 3.—Mean number of beetles[1] per square foot of bark on the top, lateral, and bottom surfaces of windthrown trees[2]

Location	Dates	Surface: Top $\overline{X}$	Top SD	Lateral $\overline{X}$	Lateral SD	Bottom $\overline{X}$	Bottom SD
Agassiz Peak, Arizona	September 5-8, 1969	76.2 a	96.2	106.9 a	95.8	183.0 b	160.0
	June 19-21, 1970	50.6 a	58.2	88.1 b	82.7	129.4 c	93.3
	September 11-13, 1970	22.3 a	33.5	56.1 b	51.5	98.2 c	72.3
Mt. Graham, Arizona	June 18-21, 1969	11.0 a	31.7	24.4 ab	34.3	36.7 b	43.6
	September 10-12, 1969	0.1 a	0.9	7.2 ab	18.6	15.8 b	30.2
Sierra Blanca, New Mexico	October 14, 1969	39.6 a	64.1	41.5 ab	59.7	85.1 b	82.1
	July 20, 1970	18.3 a	28.9	33.9 ab	47.4	58.3 b	62.7
Philmont Ranch, New Mexico	July 9-13, 1969	8.2 a	27.2	26.2 a	44.5	51.3 b	71.9
	August 12-14, 1969	6.4 a	28.0	16.6 a	33.2	42.2 b	59.7
Polvadera Mesa, New Mexico	May 25-28, 1970	4.3 a	14.2	10.7 ab	23.3	20.2 b	44.5
Hidden Valley, Colorado	September 5, 6, 1973	9.3 a	38.7	28.6 a	117.5	31.1 a	88.2
Iron Creek, Wyoming	July 7-10, 1970	2.9 a	11.6	50.9 b	49.5	60.4 b	45.2
	August 30, 31, 1970	0.4 a	2.6	37.7 b	41.6	46.3 b	46.6

[1] *Beetles include all stages of brood and a few parent adults.*
[2] *Means within specific sampling dates that are followed by the same letter are not significantly different (P = 0.05)*

From the data for standing trees, compute the average diameter of the dominant-codominant trees. Compare the diameter to table 4 and derive the number of beetles required to cause mortality of that size of tree. Divide the number of beetles required to kill a certain size of tree into the potential number of attacking beetles to derive the number of potentially infested trees.

Data from Iron Creek can be used as an example. Assume: mean number of beetles per square foot ($\bar{X}$) = 31 (table 3), number of windthrown trees (N) = 100 (actually less than 100 in table 1 but assumed to be 100 for these calculations), average diameter of infested length (d) = 15 inches (1.25 feet) (unpublished data), average infested length (l) = 61 feet (unpublished data), average d.b.h. of standing trees = 19 inches (note this diameter is greater than the average diameter of infested length because latter diameter represents the midpoint of the infested length). The average infested bark area = πdl = $3.14 \times 1.25 \times 61 = 239$ square feet. The potential number of beetles available for attack (P) = $31 \times 239 \times 100$ = 740,900. For a stand with average d.b.h. of 19 inches, 740,900 beetles could infest 521-945 trees (740,900 divided by number of beetles necessary to cause mortality of 19-inch tree from table 4).

Predictions made with this method will overestimate the number of potentially infested trees because beetle numbers will be further reduced through overwintering and dispersal mortality. However, the estimate will be useful in assessing potential tree mortality. The potential problem can be evaluated further by comparing the average diameter of standing trees and other stand characteristics to the risk levels of the characteristics used in the stand rating scheme. When future studies define overwintering and dispersal mortality, this prediction scheme will become more accurate and more useful.

Table 4.—Number of attacks and beetles to cause mortality in a tree of specific d.b.h. Based on attack densities from Frye et al. 1977 and Knight 1960. Published in Schmid and Frye 1977

Diameter	Frye et al. 1977		Knight 1960	
	Number of attacks	Number of beetles	Number of attacks	Number of beetles
7	67	135	111	222
8	97	195	159	317
9	140	280	226	452
10	171	342	282	564
11	204	409	343	685
12	232	463	399	798
13	259	518	463	925
14	276	553	495	989
15	303	607	541	1082
16	317	635	568	1135
17	334	669	600	1199
18	366	732	660	1319
19	392	784	711	1422
20	412	823	745	1489
21	431	862	780	1559
22	458	916	831	1662
23	484	968	880	1760
24	506	1013	921	1842
25	530	1060	965	1929

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